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LESTR-2
Telemetry Ground System

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

LESTR-2 TELEMETRY GROUND SYSTEM

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Group 63

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ABSTRACT

A new telemetry ground station identified as LESTR-2 and intended for use with LES-5 and LES-6 satellites is described for the purpose of defining interface requirements and available outputs. Like the previous ground station, LESTR-2 provides a printed paper-tape output as well as a magnetic-tape output. In addition, however, it includes a number of new features and outputs such as selectable-word printout from a second printer, telephone data-set output for remote real-time data processing, and automatic frame-format identification.

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Franklin C. Hudson
Chief, Lincoln Laboratory Office

LESTR-2 TELEMETRY GROUND SYSTEM

I. LESTR-2 GENERAL DESCRIPTION

LESTR-2 is the Lincoln Experimental Satellite Telemetry Receiver - 2nd model. It is intended to accept the rf telemetry signal output of LES-6 and from this provide the following:

(a) Printout on paper tape of all telemetry data.

(b) Printout on a separate auxiliary paper tape of selected telemetry data.

(c) Magnetic-tape recording of all telemetry data.

(d) Data set output of telemetry data for real-time computer processing via telephone link.

(e) Command system synchronization.

A block diagram of the overall system is shown in Figure 1. Except for the auxiliary paper-tape printer, LESTR-2 is contained within a single cabinet which can be rolled between locations as required.

The Logic Unit has been implemented with TTL integrated-circuit logic and has been designed for operation with either LES-5 or LES-6. While the basic input circuitry for processing the incoming telemetry data stream is very similar to that in the previous ground station, a number of refinements and additions have been made to the overall system. These include facility for printout of selected data on a second paper tape printer, facility for operation of a data set telephone link to the computer center for real-time data processing, and facility for detection and output of frame and format identification.

II. LOGIC UNIT INPUT

Input to the Logic Unit from the RF Unit is provided on two lines: data and clock. Both lines must switch TTL inputs in the Logic Unit. The data is non-return-to-zero. The clock is a 100 Hz square wave locked to the LES-6 telemetry signal. The negative transitions of this clock signal time sampling of the data line state within the Logic Unit, i.e. at each negative transition, the state

of the data-line input is sampled. If the state is identical to that at the previous sampling time, a binary zero is sensed; if different, a binary one is sensed. The Logic Unit includes no clock-data phase adjustment and therefore depends upon proper phase relation being established in the RF Unit.

The clock-line input is used as a basis for all timing within the Logic Unit and for this purpose both positive and negative transitions are used for timing. By utilization of both transitions, a synchronized 200 hz clock is derived to control magnetic recording and data set transmission. The squareness and frequency at the clock input must therefore be controlled accordingly and must not include any spurious transitions of sufficient magnitude to switch the TTL input circuitry.

III. LESTR-2 TELEMETRY DATA IDENTIFICATION

Telemetry data from LES-5 and LES-6 is identified according to Figure 2. The illustrated hierarchy of organization consists of bits, words, frames, formats and groups. Within each level of data organization, sequential identification is made starting with the count zero.

1 word	=	8 bits, 0 to 7
1 frame	=	32 words, 0 to 31
1 format	=	8 frames, 0 to 7 for LES-6
	=	4 frames, 0 to 3 for LES-5
1 group	=	8 formats, 0 to 7 for LES-6
	=	16 formats, 0 to 15 for LES-5

Starting with the count zero is significant in that previous frame and format identifications have been made starting with the count 1. The change has been made primarily because the numerous frame-format identifications within LESTR-2 could be implemented most simply in this manner.

Although the LESTR-2 Logic Unit has been designed for receipt of both LES-6 and LES-5 telemetry, compliance with LES-6 requirements has been emphasized. Accordingly the frame format count is made on the basis of LES-6 only, i.e. 8 frames/format, 8 formats/group. The resulting count is

an octal frame count of the 64 frames making up a group for both LES-6 and LES-5. Wherever a frame-format count is provided as an output or required as a switch setting, it is as this octal count, even if the system is synchronized to LES-5 telemetry.

The relation of LESTR-2 format-frame identification to LES-5 and 6 identification is listed in Table 1, where LES-5 and 6 counts are defined as starting with one.

The LESTR-2 format-frame identification is generally associated with the word count within a frame to identify a word. The resultant LESTR-2 word identification therefore contains up to four digits which provide a concise identification of both LES-5 and 6 words, e.g.

LESTR-2 Word 1528 = Word 28 in LESTR-2 frame 5 of LESTR-2 format 1

From the relations of Table 1, the following equivalences are also valid.

LESTR-2 Word 1528 = Word 28 in decimal frame 13

= Word 28 in LES-5 frame 2 of LES-5 format 3

= Word 28 in LES-6 frame 6 of LES-6 format 1

LESTR-2 Word 528 = Word 28 in LESTR-2 frame 5 of <u>all</u> formats

= Word 28 in LES-6 frame 6 of <u>all</u> LES-6 formats

For a word to repeat once per LES-5 frame, it must be included twice per LES-6 frame, e.g.

LESTR-2 Word 1/528 = Word 28 in LESTR-2 frames 1 and 5 of all formats

= Word 28 in LES-5 frame 2 of <u>all</u> LES-5 formats

For words repeating every frame, the word identification is simplified further, e.g.

LESTR-2 Word 28 = Word 28 of all frames and formats

IV. FRAME SYNCHRONIZATION

Frame synchronization information is provided within each telemetry frame by words 00 and 31. These words consist of a fixed bit pattern transmitted every other frame and the complement of this pattern in intervening frames. The specific pattern is shown in Figure 3.

Frame synchronization is accomplished by a continuous check of the incoming bit stream for the pattern defined in Figure 3. If data is received without error, the pattern will be found once every other frame and when it is, the word identification shown in Figure 3 is assumed to exist and the bit and word counters within LESTR-2 are reset accordingly.

This method of frame synchronization is similar to that used previously and assumes negligible probability of spoofing by any telemetry data bit patterns.

V. FRAME-FORMAT COUNT SYNCHRONIZATION

The Logic Unit of LESTR-2 includes facility to count frames and formats being received and to synchronize this count automatically.

Counting is accomplished by a three-stage binary frame counter followed by a three-stage binary format counter, the frame counter being advanced at the end of each frame.

Synchronization of the counters is manually controlled by the "Frame-Format Sync Control" switch on the LESTR-2 panel. Three positions are available: "LES-5", "OFF", and "LES-6".

With "LES-6" selected LESTR-2 will check the content of word 1 in every frame received. Upon detection of all ones (decimal 255) followed by a proper check word (word 5), frame zero is identified and the frame counter reset to zero. Similarly LESTR-2 will check the content of word 6 of the first frame of every format received. Again, upon detection of all ones followed by a

proper check word (word 10), format zero is identified and the format counter reset to zero.

With "LES-5" selected, operation is similar. For frame counter sync, the content of word 2 of every frame is checked. Upon detection of 010000000 (decimal 64) followed by a proper check word, frame zero is identified. However, since a LES-5 format contains only four frames rather than eight, only the first two stages of the LESTR-2 frame counter are reset to zero. For format counter sync, the content of word 7 of every frame for which the first two stages of the frame counter read zero is checked. Upon detection of 11110100 (decimal 244) followed by a proper check word, format zero is identified and the format counter, as well as the third stage of the frame counter, is reset to zero.

With "OFF" selected, no synchronization is provided and the frame and format counters are allowed to free run.

VI. PAPER TAPE PRINTOUT

The paper-tape printout of LESTR-2 is illustrated in Figure 4. Data words, together with format, frame, and word count for each are printed for words 1 through 30 of each frame. Words 31 and 00 are for synchronization only and are not printed. However, at the beginning of each frame during word 00, time-of-day information is printed as shown.

LESTR-2 checks the content of check words 5, 10, 15, 20, 25, and 30 and if the content is not correct, a "-" is printed to the right as shown. This indicates an error in the preceding set of four data words.

Selected data printout is provided as an auxilliary output from a separate printer. In this case, printout entries for selected words are identical to those in Figure 4, except that printout is restricted according to the selection made. Up to five words may be selected by panel switches set to the appropriate LESTR-2 word identification. Selection of LESTR-2 word XX00 (where XX is any desired format-frame count) will result in printout of time-of-day information.

So long as the format-frame count is synchronized with either LES-5 or LES-6, the format-frame count will be printed out as shown in Figure 4. However, if synchronization is inhibited by setting the "Frame-Format Sync Control" to "OFF", format-frame counts will not be printed and an entry of "-- " will be printed instead.

As an adjunct to the auxilliary printer, a strip chart recorder and D/A converter is included. This will allow plotting of telemetry data vs. time from a single selected channel.

VII. MAGNETIC TAPE OUTPUT

The manner in which telemetry data is recorded for magnetic tape output is defined in Figure 5. Each frame of recorded data corresponds to one frame of received telemetry data and includes time-of-day and site identification information as well as received telemetry data. Telemetry data, and all other information, is recorded in BCD code as indicated.

Two modes of normal recording are provided. Selection is determined by setting of the "Frame-Format Sync Control" switch, which also controls the mode of frame-format counter synchronization as discussed with regard to frame-format count.

With the "Frame-Format Sync Control" switch in either the "LES-5" or "OFF" position, data will be recorded as previously recorded for LES-5, i.e. no frame-format count information will be recorded and a P or F will be recorded after every check word to indicate whether the check word has passed or failed a check for proper content.

With the switch in the "LES-6" position, data will be recorded as defined in Figure 5 with frame and format count information included. As an indication of this recording mode, a "K" is substituted for the "S" in character 12. Also no P or F indication will be recorded. This has been omitted to limit the amount of recorded data and because a check of the telemetry check word can be made by tape processing programs.

Normal record length for LESTR-2 is 256 frames. A record will always begin with frame zero of format zero as indicated by the frame-format counters. Once begun, a record cannot be terminated until the required 256 frames are completed. This corresponds to four groups of 64 frames and will require a run of approximately 11 minutes.

When tape is loaded, a beginning-of-tape gap of at least 3.4 inches beyond the beginning-of-tape marker will be produced automatically. Thereafter, a record gap will be inserted by LESTR-2 at the end of each record.

At the end of a tape, one or more file gaps will be inserted by manual operation of the recorder.

All recordings will be made on 1200-foot reels which will allow approximately 18 hours of continuous recording.

For unattended operation, LESTR-2 includes facility for recording during a preselected interval. This feature utilizes the time-of-day clock required for recording time information.

For recording test data, LESTR-2 also includes facility for recording short records consisting of a single format or a single group only upon pushbutton command.

VIII. TELEPHONE DATA SET OUTPUT

For real-time computer processing of telemetry data, LESTR-2 contains a 103 Data Set which can feed data directly to a 2702 terminal in the Lincoln Laboratory computer center. The data set signal is defined in Figure 6.

Data is transmitted as 8-bit words, one word being transmitted for every telemetry word received. To provide time-of-day information to the computer, telemetry check words are replaced by the time-of-day information and a single-bit indication of check word content as determined by LESTR-2.

Frame synchronization is provided by alternate sets of all ones and all zeros transmitted in word 31 of each frame. When enabled, transmission will always begin with word 31. Further, the first word 31 will always consist of all ones.

Transmissions will terminate at the end of word 30. Since data words within each frame may also consist of all ones or zeros any synchronization program must check the periodicity of true sync to avoid being spoofed.

Error checking is provided by parity bits shown in Figure 6. A single parity bit is transmitted at the end of word 0 to provide an odd parity check over words 31 and 0. Also a single parity bit is transmitted at the end of each time-of-day word to provide an odd parity check over this and the preceding set of four data words. Since this latter parity extends over 5 x 8 or 40 bits, it is not a very powerful check. However, a more sophisticated and consequently more complex check does not appear warranted for initial operation.

IX. COMMAND SYNC OUTPUT

Operation of the ground command system requires synchronization with operation of the satellite telemetry. For this purpose, two outputs are available from LESTR-2: a slow command sync and a fast command sync. These are defined in Figure 7. For the slow command sync, LESTR-2 includes switch control of the output polarity. For fast command sync, a rotary switch is included to provide incremental delays in the 6.25 Hz square wave output from 0 to 140 ms in 20 ms steps.

TABLE 1

LESTR-2 Format-Frame Identification

Decimal Fr. Count	LESTR-2 For.-Fr.	LES-5 For. Fr.	LES-6 For.-Fr.	Decimal Fr. Count	LESTR-2 For.-Fr.	LES-5 For.-Fr.	LES-6 For.-Fr.
00	00	16-1	8-1	32	40	8-1	4-1
01	01	16-2	8-2	33	41	8-2	4-2
02	02	16-3	8-3	34	42	8-3	4-3
03	03	16-4	8-4	35	43	8-4	4-4
04	04	1-1	8-5	36	44	9-1	4-5
05	05	1-2	8-6	37	45	9-2	4-6
06	06	1-3	8-7	38	46	9-3	4-7
07	07	1-4	8-8	39	47	9-4	4-8
08	10	2-1	1-1	40	50	10-1	5-1
09	11	2-2	1-2	41	51	10-2	5-2
10	12	2-3	1-3	42	52	10-3	5-3
11	13	2-4	1-4	43	53	10-4	5-4
12	14	3-1	1-5	44	54	11-1	5-5
13	15	3-2	1-6	45	55	11-2	5-6
14	16	3-3	1-7	46	56	11-3	5-7
15	17	3-4	1-8	47	57	11-4	5-8
16	20	4-1	2-1	48	60	12-1	6-1
17	21	4-2	2-2	49	61	12-2	6-2
18	22	4-3	2-3	50	62	12-3	6-3
19	23	4-4	2-4	51	63	12-4	6-4
20	24	5-1	2-5	52	64	13-1	6-5
21	25	5-2	2-6	53	65	13-2	6-6
22	26	5-3	2-7	54	66	13-3	6-7
23	27	5-4	2-8	55	67	13-4	6-8
24	30	6-1	3-1	56	70	14-1	7-1
25	31	6-2	3-2	57	71	14-2	7-2
26	32	6-3	3-3	58	72	14-3	7-3
27	33	6-4	3-4	59	73	14-4	7-4
28	34	7-1	3-5	60	74	15-1	7-5
29	35	7-2	3-6	61	75	15-2	7-6
30	36	7-3	3-7	62	76	15-3	7-7
31	37	7-4	3-8	63	77	15-4	7-8

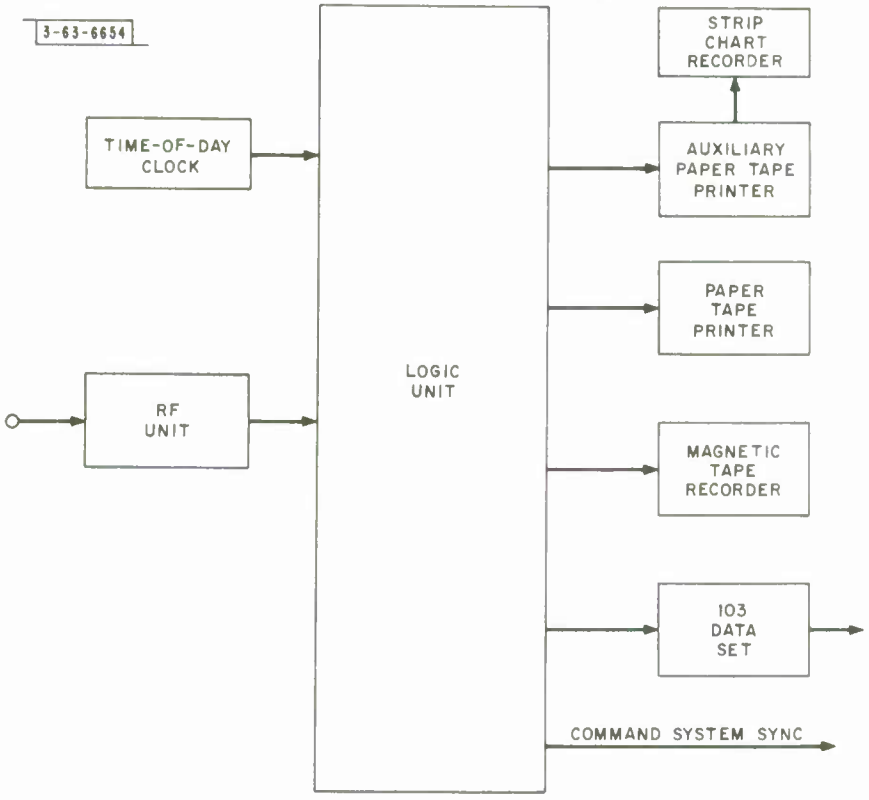
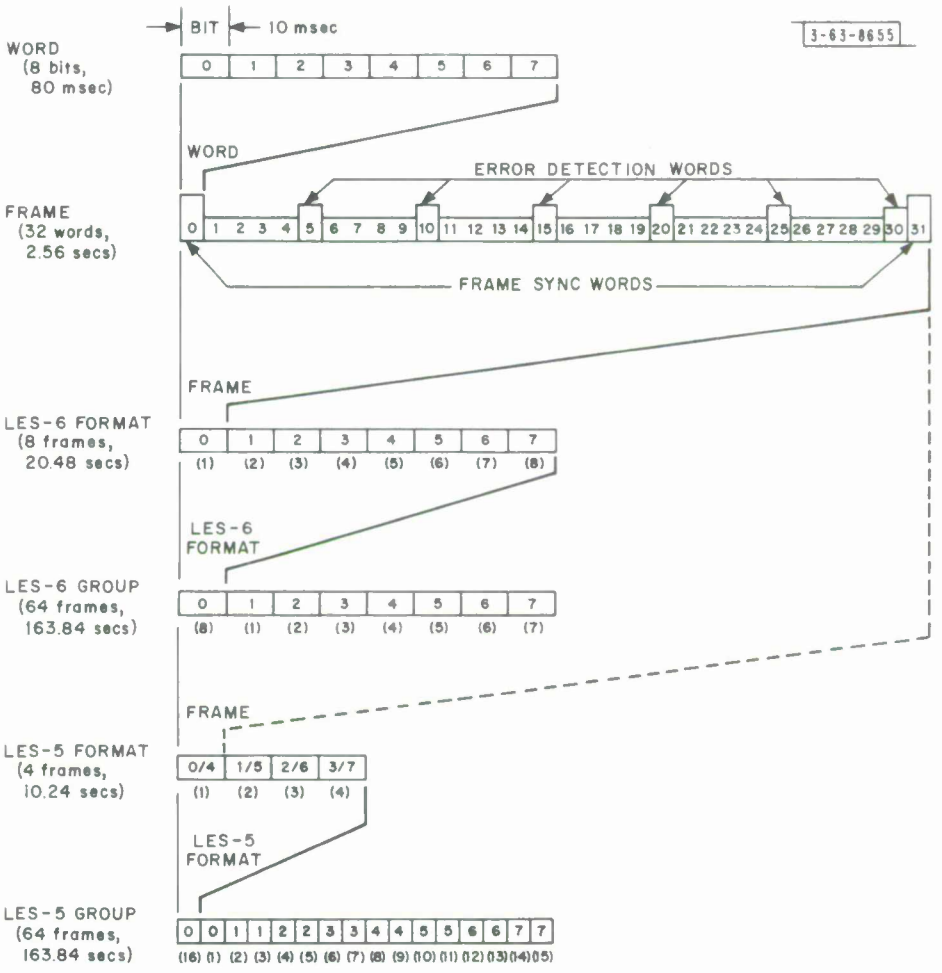


Fig. 1. LESTR-2 block diagram.



Parenthetical Frame And Farmat Numbers Indicate Carresponding Identificatian In Satellite Telemetry Systems

Fig. 2. LESTR-2 data identification.

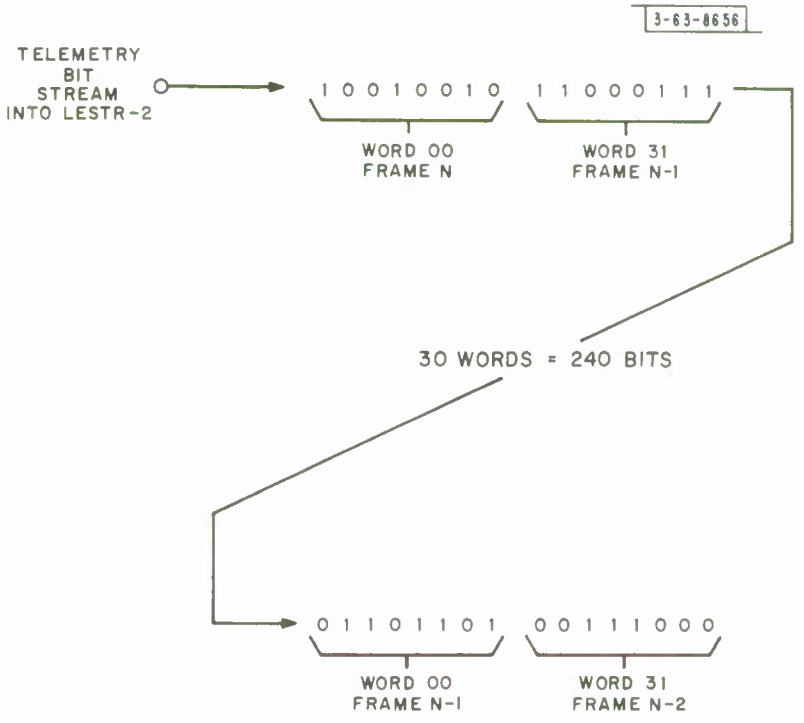
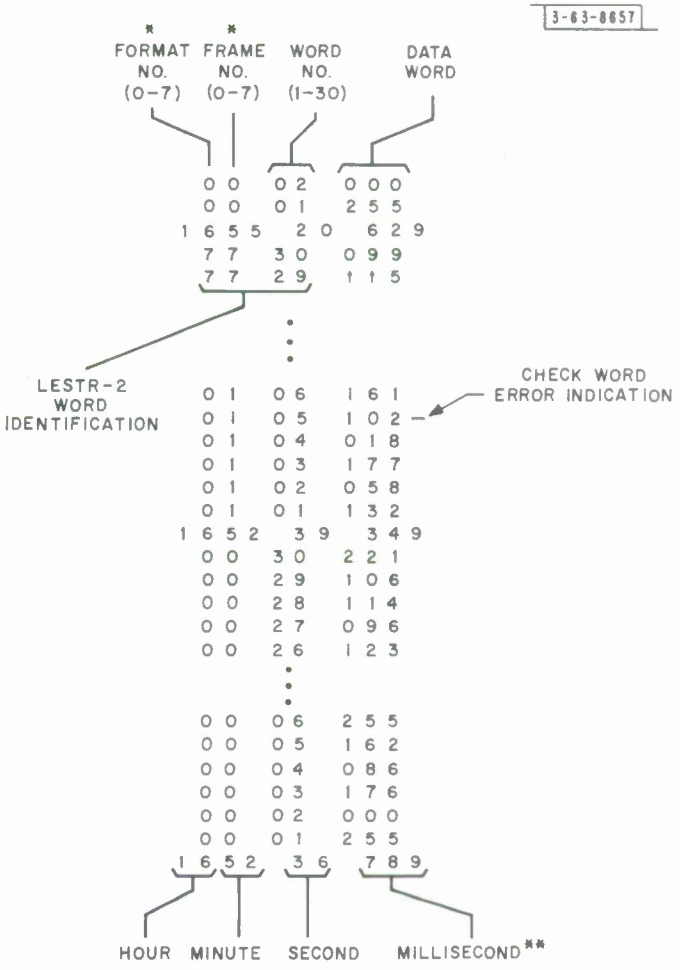


Fig. 3. Telemetry frame sync pattern.

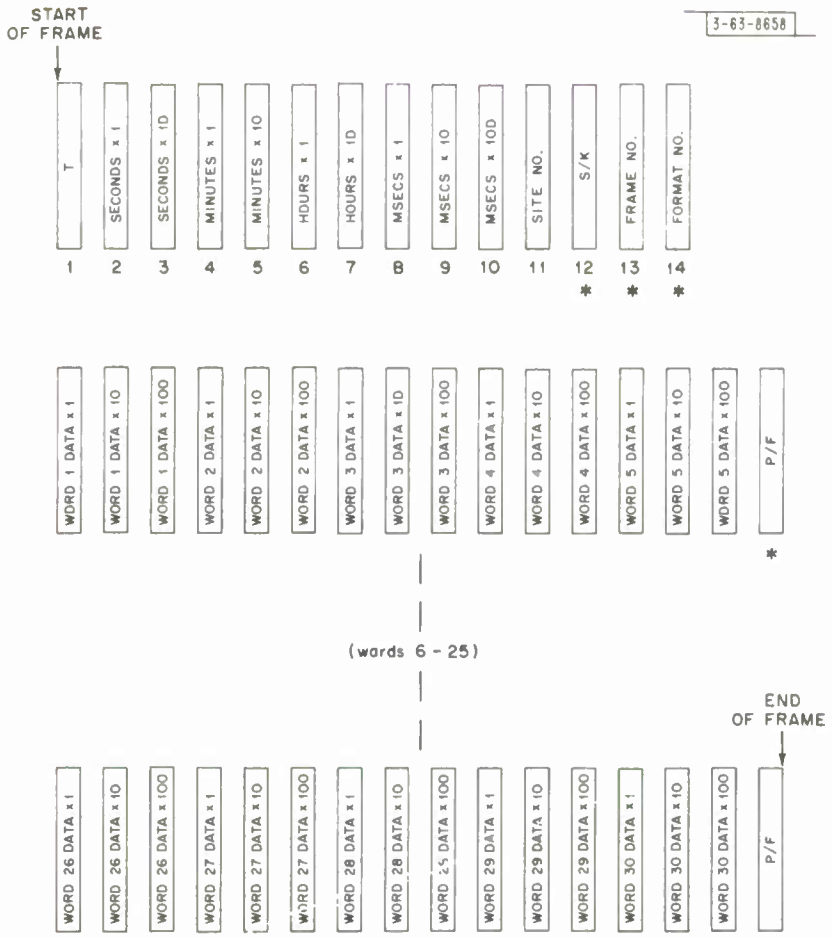


(Hypothetical data shown)

*Printout according to LES-6 telemetry, i.e., 8 frames/format, 8 formats/group. Equals octal frame count for both LES-5 and LES-6.

**Time at which bit 0 of word 00 from satellite is sampled at LESTR-2 Logic Unit Input.

Fig. 4. LESTR-2 paper tape printout.

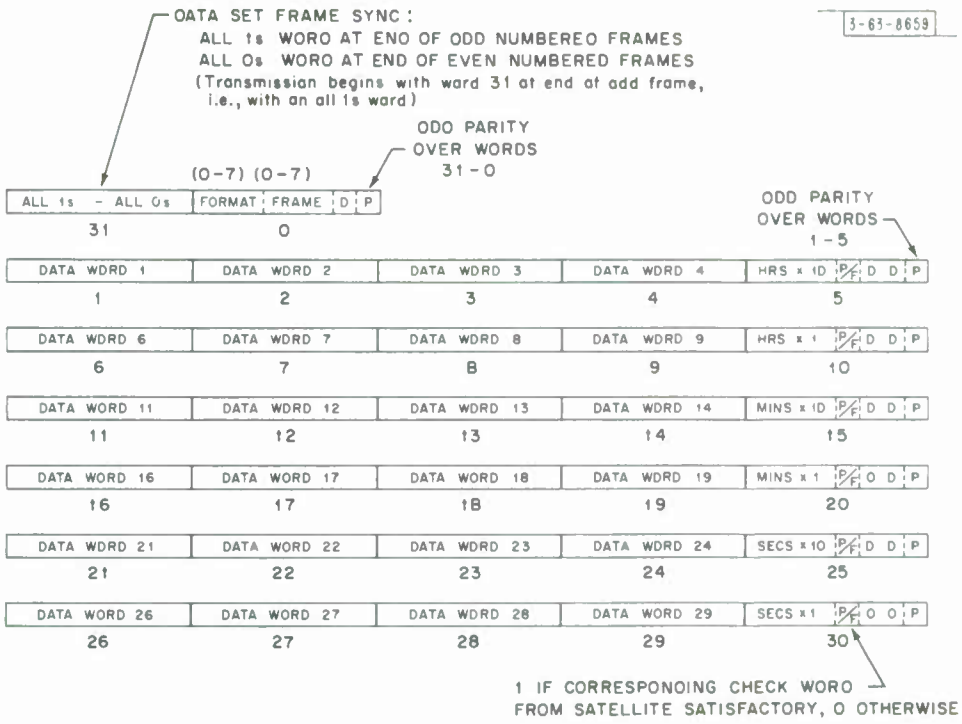


* "Frame-Format Sync Control Switch Setting

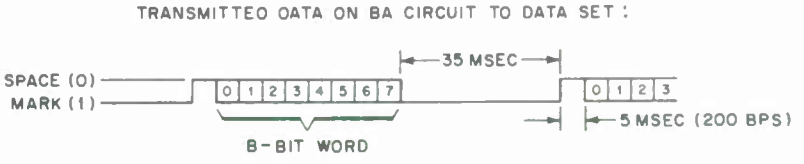
Char. 12	Char. 13 and 14	P/F Char.	Char. per Frame
LES-5	S	Omitted	Included	108
Off	S	Omitted	Included	108
LES-6	K	Included	Omitted	104

All Recording 7-Track BCDIC, Even Parity, 200 BPI
Normal Record Length : 256 Frames (4 groups)

Fig. 5. LESTR-2 magnetic tape output.



All Data Wards In Binary Farm
All Other Wards In BCD Farm
All Information Transmitted mast Significant Bit First



One Word Transmitted for Each Telemetry Word Received from Satellite.
Bit Rate Derived from Satellite.

Fig. 6. LESTR-2 output to telephone data set.

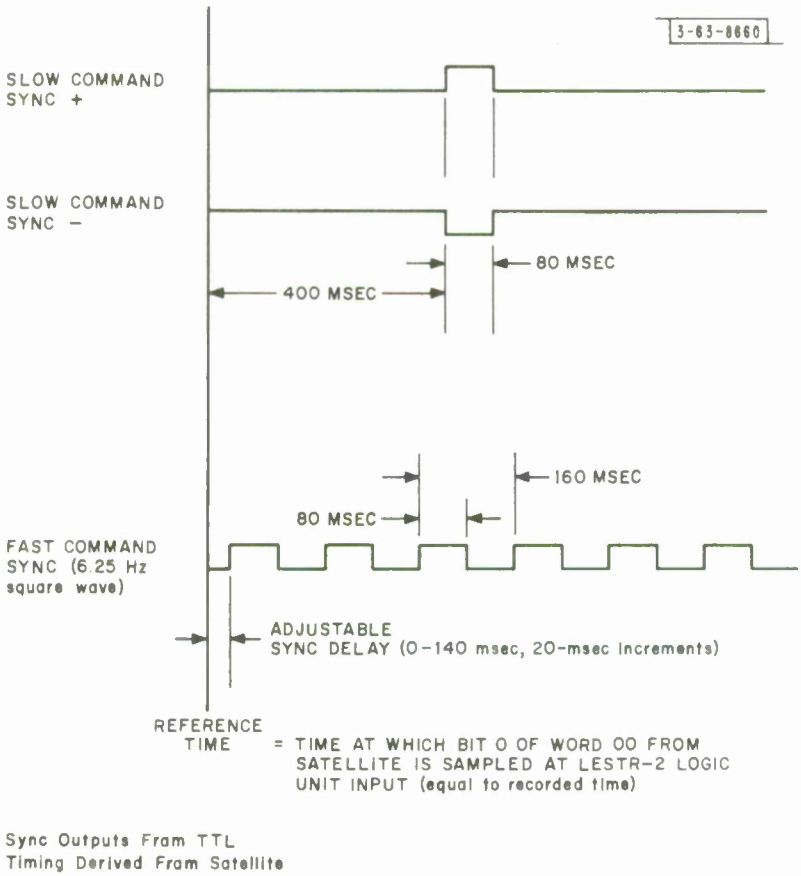


Fig. 7. LESTR-2 command sync output.

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13. ABSTRACT

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14. KEY WORDS

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